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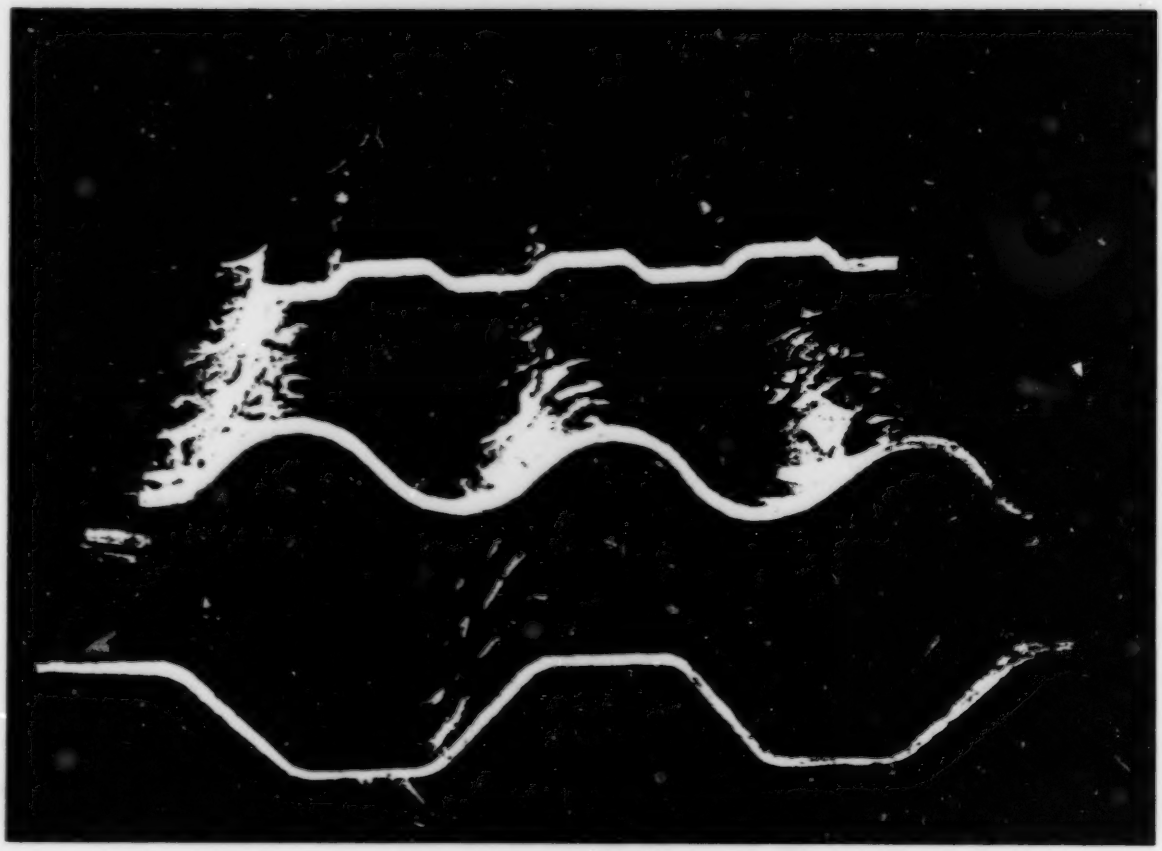
Manufacture of Corrugated Waferboard (Waveboard™)



ALBERTA RESEARCH COUNCIL

Industrial Technologies Department

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Open File Report #1988-05

Manufacture of Corrugated Waferboard (Waveboard™)

by
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INDUSTRIAL TECHNOLOGIES DEPARTMENT, ALBERTA RESEARCH COUNCIL
EDMONTON, ALBERTA, CANADA, MARCH 1988

Summary

Improvements in the performance characteristics of flat waferboard and OSB have been attained by optimization of such parameters as wafer geometry, resin content, resin type, panel density, additives and the like. However, existing manufacturing technology would appear to have exhausted these possibilities for increasing structural strength.

In an attempt to improve the flexure strength characteristics of waferboard panels, the Alberta Research Council and B.S.L. Machine Ltd. of Edmonton, Canada designed and constructed a pilot plant press and a process for the industrial manufacture of corrugated waferboard. We designed a unique press platen assembly having a working surface which can be mechanically converted between planar and corrugated configurations to overcome the problems associated with a fixed male/female press platen system.

Corrugated waferboard (Waveboard™) was manufactured with approximately 28 times higher stiffness and about 6 times higher bending strength than flat waferboard of the same thickness and weight.

The use of Waveboard™ in construction could extend practical design spans far beyond those possible with the flat waferboard (and OSB) produced today.

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Introduction

General

"The history of the building products industry is one of never-ending search for new and better materials – materials of greater stiffness and strength that will span wider spaces and, thereby, reduce the cost and complexity of building construction. This has been true with wood, as with other materials" – Quote from R. Ferguson.

The construction industry throughout the world for years has used corrugated sheeting material of metal, plastic and asbestos cement for roofing and cladding industrial buildings. The inherent stiffness and strength of corrugated materials are well understood. But no potential commercially viable method for manufacturing corrugated waferboard sheeting and structural materials was known.

A few years ago the Alberta Research Council's Forest Products Working Group suggested a project on corrugated waferboard (figure 1) in response to the Alberta Government's interest in improved aspen wood utilization.

In October 1985 the first corrugated waferboard (Waveboard™) was manufactured using an apparatus and a process invented by L. Bach and E. Stark. In July 1986 a series of waveboard panels was manufactured and tested at the Alberta Research Council Forest Products Laboratory in Edmonton, Alberta. U. S. patents were issued in October 1986 and in June 1987.

Waveboard™ is a fourth-generation engineered wood composite panel, having evolved from particleboard, waferboard and oriented strandboard.

The advantage of Waveboard™ as a building material is its markedly increased stiffness/weight and strength/weight ratios, which for example, give builders increased flexibility with regard to spacing of floor joists and roof trusses.

In terms of performance features, Waveboard™ will be economical compared with other corrugated materials. Because it is an inexpensive wood composite, it is expected to open new markets for wood.

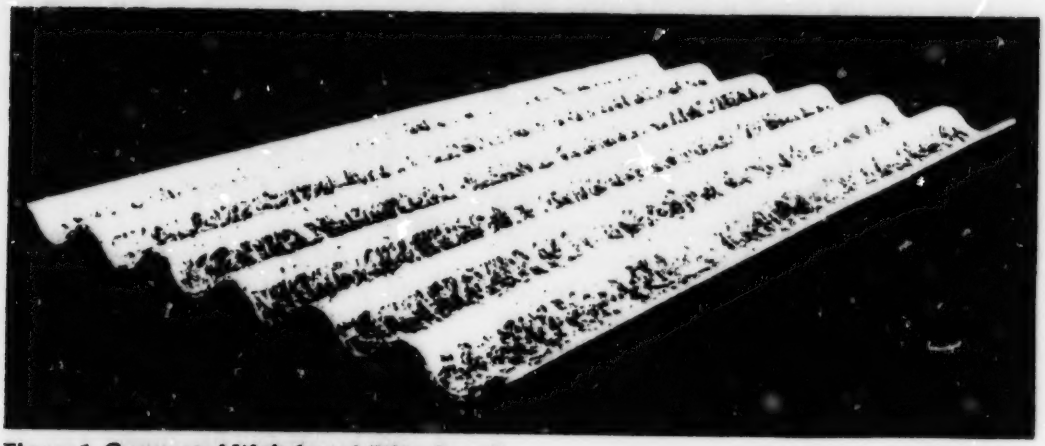

Figure 1. Corrugated Waferboard (Waveboard).

Goals and Objectives

The objective of this paper is to give an overview of some aspects of the Alberta Research Council's initial work on corrugated waferboard (Waveboard™).

The waveboard project objectives were:

a. to conceive, design and construct a pilot prototype apparatus for manufacturing corrugated waferboard;
b. to develop a mathematical model for theoretical predictions of the structural stiffness and strength of various potential profiles for waveboard;
c. to develop a manufacturing process suitable for laboratory manufacture of corrugated waferboard panels of 2' x 3' (610 x 914 mm) dimension;
d. to manufacture and test waveboard with aspen wood strands, resin content and panel density comparable to that of OSB presently being produced in Alberta, Canada.

Background

Typically, a waferboard panel comprises layers of wood flakes or wafers formed into a composite structure using a resinous binder. The preparation of waferboard panels is complex, but broadly consists of two principal stages. The first stage involves preparation of the wafers and mixing them with the binder to form a loose layer or mat; the second stage involves subsequent compression and heating of the mat to cure the resin and form the consolidated panel.

At present, waferboard is manufactured in the form of planar or flat sheets. The cost of production of such waferboard panels is economically attractive, because a low-grade timber may be utilized as the raw feedstock. Waferboard is a recognized structural panel, finding wide application in the construction industry, particularly as a plywood substitute in residential construction.

Inherent disadvantages of conventional planar wood panels such as waferboard, OSB, and plywood, reside in their relatively low structural stiffness and strength.

Improvement in the performance characteristics of flat waferboard (flatboard) panels has been attained by optimization of such parameters as wafer orientation, wafer geometry, resin selection and content, and the like. However, existing technology would appear to have almost exhausted these possibilities for increasing structural strength.

In an attempt to improve the longitudinal flexural stiffness and strength characteristics of waferboard panels, we considered a waferboard panel having a corrugated configuration. The fundamental concept of corrugating sheeting materials to thereby improve the structural properties is *not* a novel one. The *method* we suggest to manufacture corrugated wood panels is a novel one.

One method which readily comes to mind, for providing a corrugated waferboard panel involves placing a flat resin-coated wood flake mat between corrugated platens and heating and compressing the mat between them. However, this approach has not been commercially successful because the mat must elongate to assume the form of the corrugated platens. Due to the unlocked state of the wafers, they tend to shift in certain portions of the mat during the compression-elongation operation, and the compressed product is characterized by density variations.

Initial work focused on avoiding this problem.

Many different wave shapes of corrugated waferboard are possible, making possible new applications in areas such as:

- subflooring
- roof sheeting
- siding
- webs for stress skin panels

- modular load-carrying building panels
- concrete forming
- packing crates, and
- pallets

Figures 2 and 3 illustrate several potential applications of waveboard.

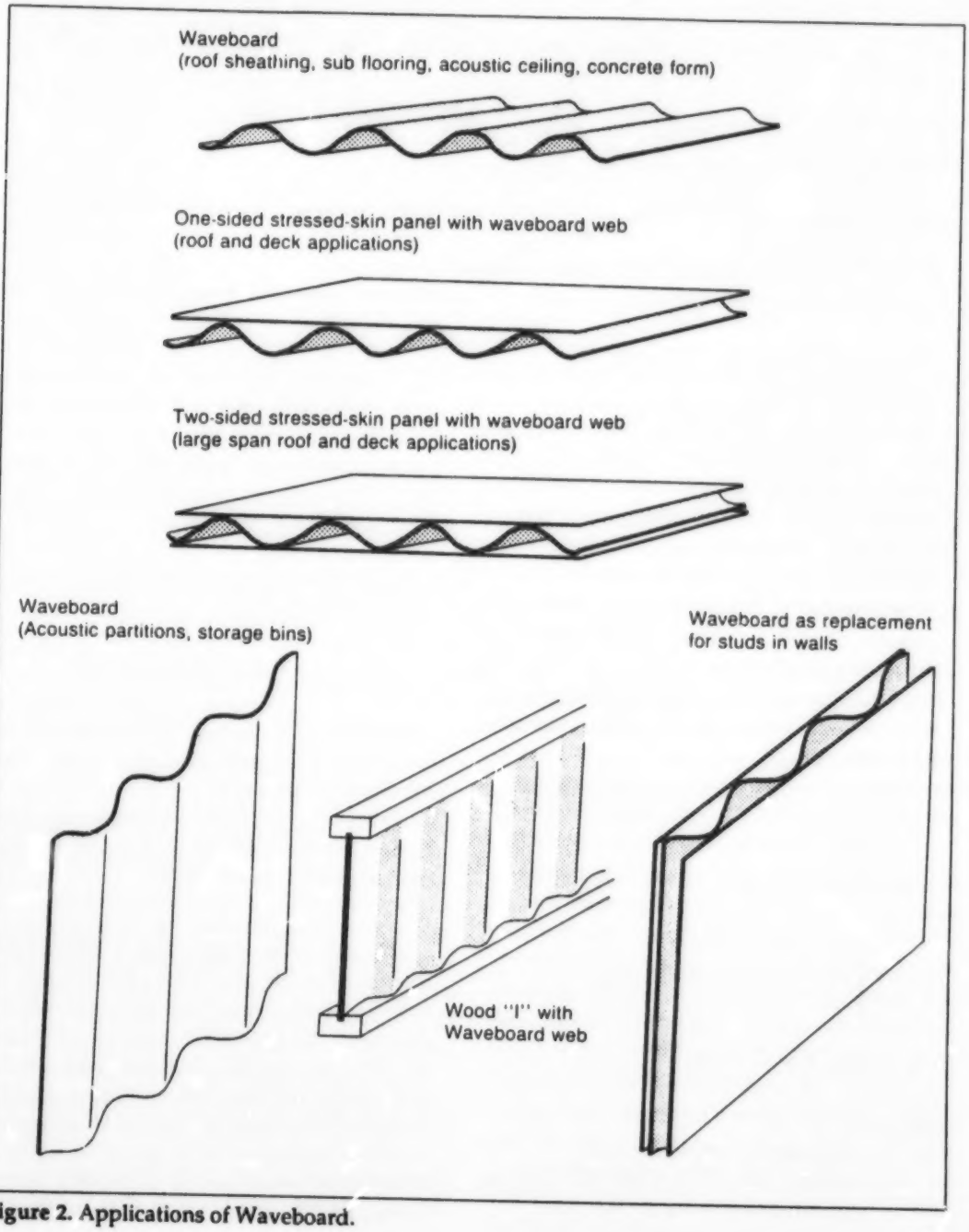
Waveboard
(roof sheathing, sub flooring, acoustic ceiling, concrete form)
One-sided stressed-skin panel with waveboard web
(roof and deck applications)
Two-sided stressed-skin panel with waveboard web
(large span roof and deck applications)
Waveboard
(Acoustic partitions, storage bins)
Waveboard as replacement
for studs in walls
Wood "I" with
Waveboard web

Figure 2. Applications of Waveboard.

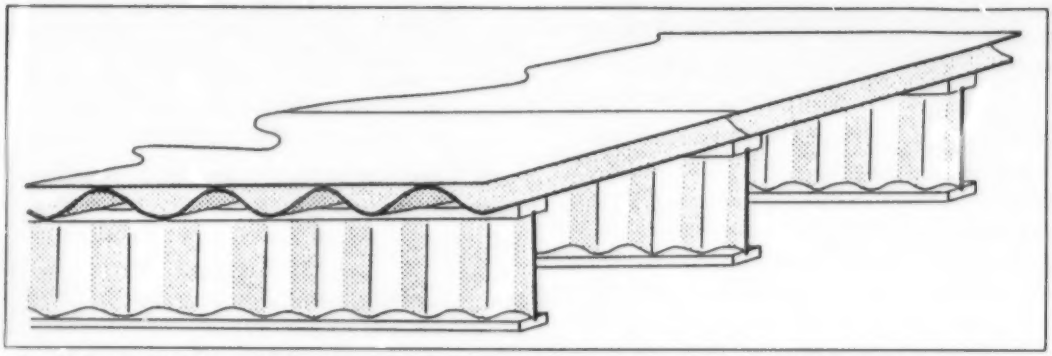

Figure 3. Application of Waveboard in roof and deck structures in industrial buildings.

Experimental Procedures

Design Considerations (Wave Shape)

Assuming the freedom of choice for the cross section properties of waveboard, the theoretical stiffness and load capacity can be estimated in advance using standard engineering mechanics principles, if the specific material properties are known.

We made the choice to study initially a sinusodial wave-shaped panel, and constructed a mathematical model to examine the influence of panel profile parameters such as wave amplitude, skin thickness and wavelength.

With reference to panel cross section in Figure 4, we have:

$$A = \int_0^{\lambda} [y_C - y_D]\, dx$$

$$I = \frac{1}{3}\int_0^{\lambda} [y_C^3 - y_D^3]\, dx - A \cdot (a + \frac{t}{2})^2$$

$$S = I/[a + \frac{t}{2}]$$

where:

- A = cross section area of panel
- I = moment of inertia with reference to the symmetry axis of the panel cross section
- S = section modulus
- y_C = curvature of upper surface section with reference to X-axis touching lower surface peaks
- y_D = curvature of lower surface section with reference to X-axis touching lower surface peaks
- λ = wavelength
- a = amplitude of the sinusodial center line of the skin
- t = skin thickness measured as normal to the sinusodial center line

With the information above, we wrote a computer program "WAVEFORM" using numerical integration subroutines to evaluate the influence of changing panel design parameters as panel depth, skin thickness and wavelength.

When evaluating model calculation results of various corrugated panels, we found it useful to compare the waveboard data with flat panels having the same cross section area, weight, thickness and specific material properties. The underlying reason being to show how much the stiffness and strength capacity of a given amount of wood (and resin) can be improved using a corrugated profile rather than a conven-

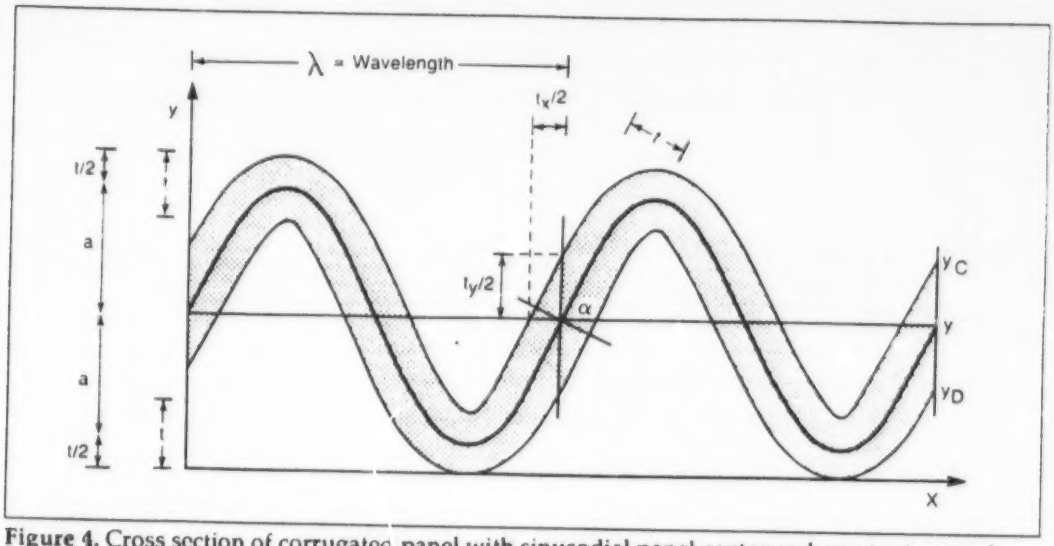

Figure 4. Cross section of corrugated panel with sinusodial panel center and constant normal thickness.

tional flat panel. With reference to Figures 5, 6, and 7, we use the following ratios:

$$\text{Relative stiffness} = \frac{E_w \cdot I_w}{E_f \cdot I_f} \cong \frac{I_w}{I_f}$$

$$\text{Relative strength} = \frac{MOR_w \cdot S_w}{MOR_f \cdot S_f} \cong \frac{S_w}{S_f}$$

where:

E	=	Modulus of Elasticity
MOR	=	Modulus of Rupture
w	=	Subscript (Waveboard)
f	=	Subscript (Flatboard)

Design Considerations (Press Platens)

Several attempts have been made over the years to use fixed male/female press platen pairs for molded structural panel products. (Geimer 1977 and Koch 1978). Attempts to make commercial corrugated structural waferboard panels with larger amplitudes and uniform skin thickness have failed.

We, therefore, set out to overcome this problem.

We designed a press platen assembly having a working surface which can be mechanically converted between planar and corrugated configurations.

In Figures 8 and 9, the mechanical principles of our press platens are illustrated. Not shown on the figures are electrical heating rods running parallel to the pins connecting the platen links.

A mat of wood wafers coated with thermosetting resin binder is deposited between upper and lower, spaced apart platen assemblies. The platen assemblies, in the planar configuration, are then pressed together to a limited extent to precompress the mat to fix the wafers.

Horizontal force is then applied to the platen assemblies to convert them to the corrugated configuration. The precompressed mat is thus forced to adopt a corrugated form. The platen assemblies are then further pressed together and heated, to cure the resin and to produce a corrugated waferboard panel.

The first laboratory press platen system was designed and built only to try out the mechanical principles in practice. With it, boards of a final dimension of 610 x 915 mm (24" x 36") with a wavelength of 190 mm (7-

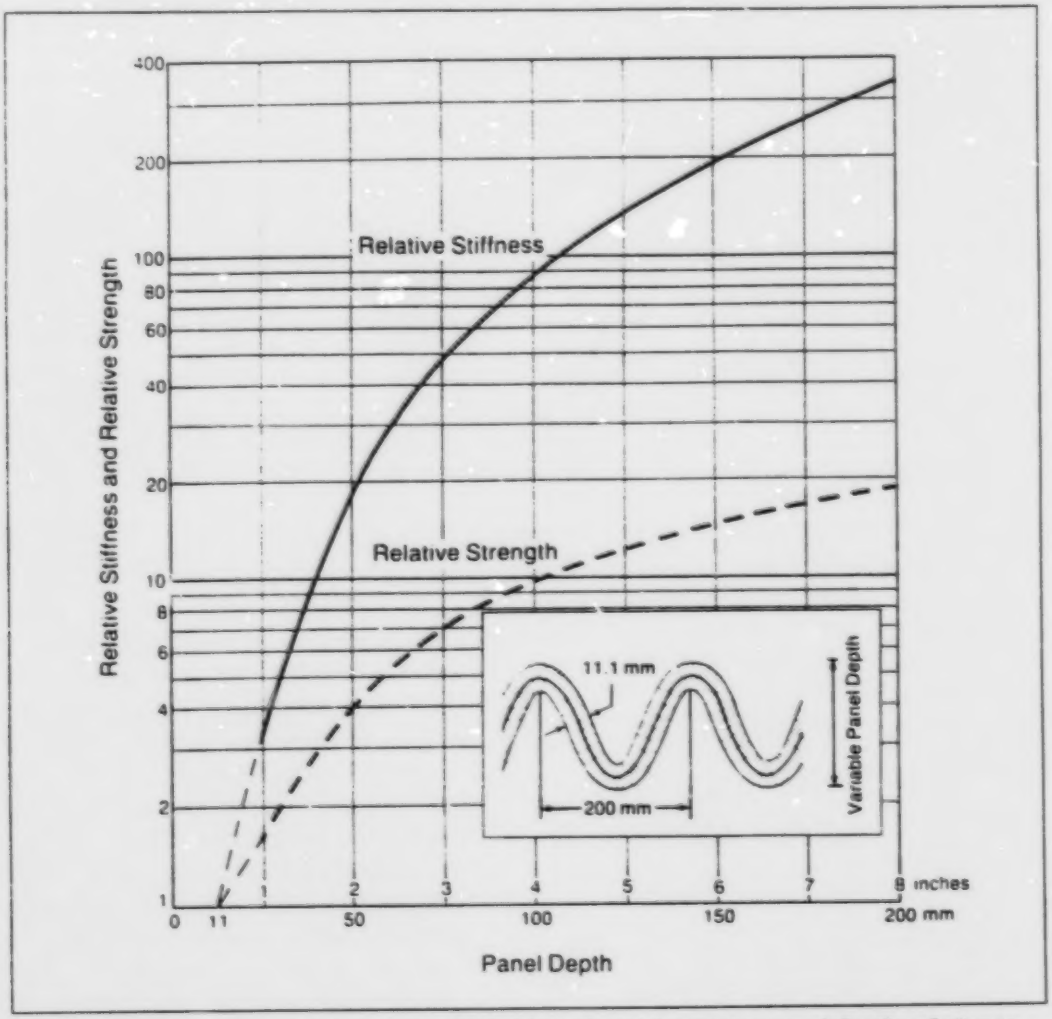

Figure 5. Bending stiffness and strength of Waveboard with increasing panel depth, relative to flat panels.

1/2"), a panel depth of 63.5 mm (2-1/2") and a skin thickness of 11.1 mm (7/16") could be pressed. However, there appears to be no technical problem in scaling up the final panel size to 1220 x4880 mm (4' x 16').

Manufacturing Process for Waveboard

General

The process by which waferboard, oriented strandboard or waveboard is manufactured follows the steps:

Furnish Preparation – Various wood species are suitable. In Canada aspen logs approximately 8' in length and 6" to 14" in diameter are used. The logs are cleaned, debarked, waferized and screened. The strand/wafer length averages 76 mm (3") and the thickness is 0.76 mm (0.03").

Drying – The moisture content of the furnish is reduced from green to a low level in large dryers. The wafers are screened after drying.

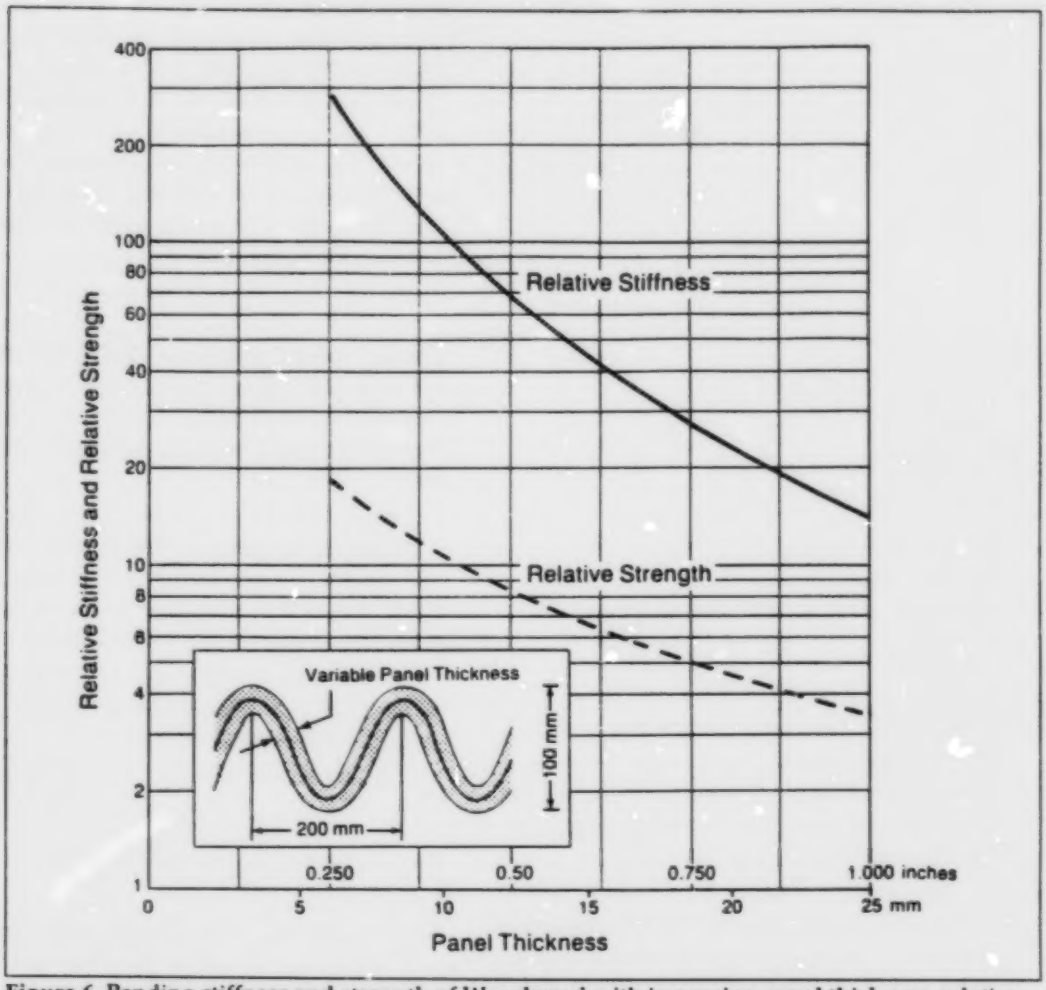

Figure 6. Bending stiffness and strength of Waveboard with increasing panel thickness, relative to flat panels.

Blending – Resin and wax are applied to the furnish: wax to improve the moisture resistance of the panel, and resin as a binder.

Forming – Wafers (or strands) are arranged loosely into a mat. The mat is formed on a caul plate, which is also used for moving the mat into the press.

Pressing – In the press the mat is subjected simultaneously to high temperature, which sets the binder, and to high pressure, which compresses the mat to specified thickness.

Finishing – The panels are cooled, trimmed, packed and stored for shipment.

Only the pressing step in making waveboard differs from normal OSB/Waferboard manufacture. This fact significantly reduces the technical risks of scaling up the waveboard technology. It also means that waveboard manufacture could be introduced fairly easily to an existing OSB/Waferboard plant.

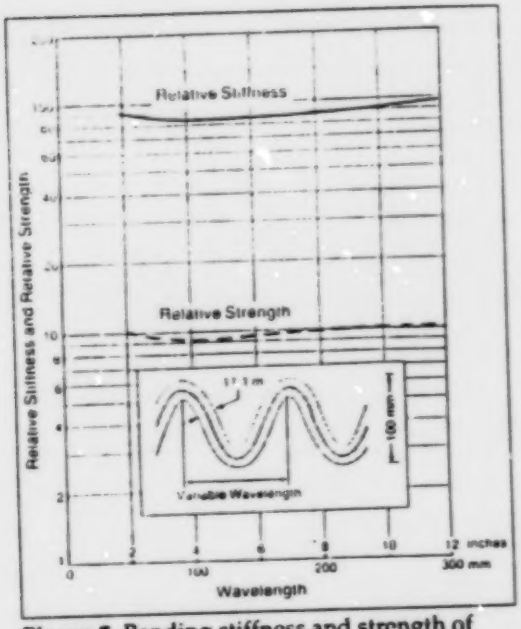

Figure 7. Bending stiffness and strength of Waveboard with increasing wavelength, relative to flat panels.

Specifics on the Manufacturing Procedure Used

The process of manufacture of corrugated waferboard (waveboard) used in this study is illustrated in Figure 10.

Preparation of Wafer Mat – The furnish used was typical industrial Alberta aspen strands. The approximate strand dimension was 75 mm long, 0.75 mm thick and 10 to 25 mm wide. At 5% MC the furnish was blended with 3% powdered P.F. resin and 1% wax in a Cancar Laboratory drum blender.

The furnish was laid out by hand between two flexible stainless screens (cauls). Talcum powder was spread over the stainless screens to prevent bonding of the wood to the screens.

Positioning Mat and Press Initialization – After the furnish and the screens were set into place on the bottom press platen as shown, the corrugated platens were moved into the 2' x 4' press. The corrugated platen temperature was 205°C. The press platens were manufactured by B.S.L. Machine Ltd., Edmonton, Alberta according to U.S. Patent No. 4,616,991 (L. Bach and E. Stark, 1986). The platens used have an open surface of 920 x 920 mm. The platen is electrically heated with heating rods running parallel to the pins in the press platens.

Precompression and Corrugation – The press was operated in the manual control mode. Once the mat was placed on the press platens (in their unfolded position), the opening was reduced in one step. At this displacement the corrugated platens were corrugated by applying a horizontal force.

Final Compression – The press opening was further reduced at this stage until the corrugated platens were at their stops. The panel was left at the stops in the press for four minutes to allow the resin to set.

Decompression and Removal of Panel – Prior to removal of the finished waveboard panel from the press, pressure was released slowly to avoid steam release damage (figure 11).

Test Methods

General Testing

The waveboard test sample dimensions and mass were recorded for all test samples. This included the high, low and average values of thickness, wavelength and depth. Density and moisture content were also calculated from the data.

Specific Materials Properties

Testing of specific materials properties of waveboard was carried out according to a slightly modified version of CSA/CAN3-0437. Waveboard's differences in specific materials properties from waferboard/OSB are minor compared to the huge differences in section properties. However, they must be considered to properly

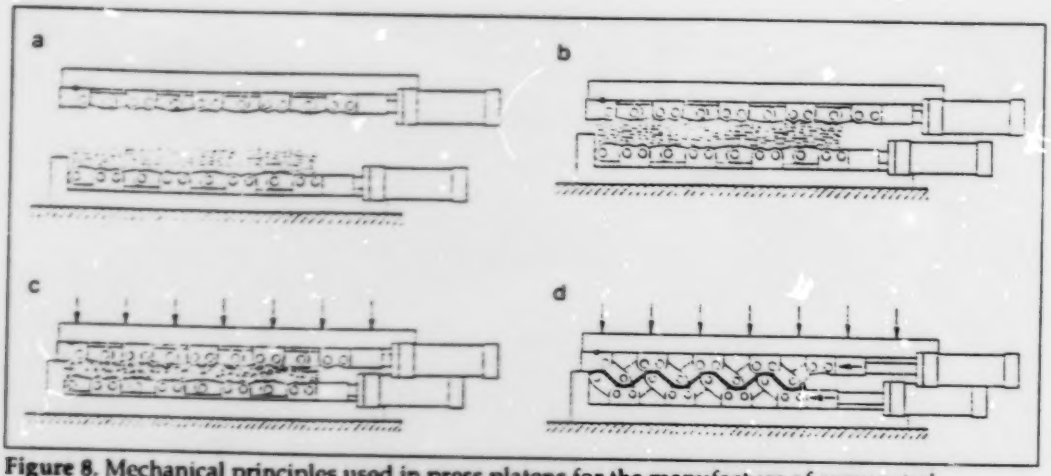

Figure 8. Mechanical principles used in press platens for the manufacture of corrugated waferboard.

evaluate the reasons for improved panel performance.

Bending Properties of 2' x 3' Waveboard Samples

Determination of flexure properties of the waveboard, where the ridges are parallel to the span, were given high priority in this study.

The laboratory manufactured waveboards were tested in full size, according to a modified method as close as practicable to ASTM D198. The test setup for flexure testing consisted of a simply support single span with a single line load at the midspan. The load vs. deflection curve and the peak load were recorded and used to calculate panel stiffness and maximum load capacity.

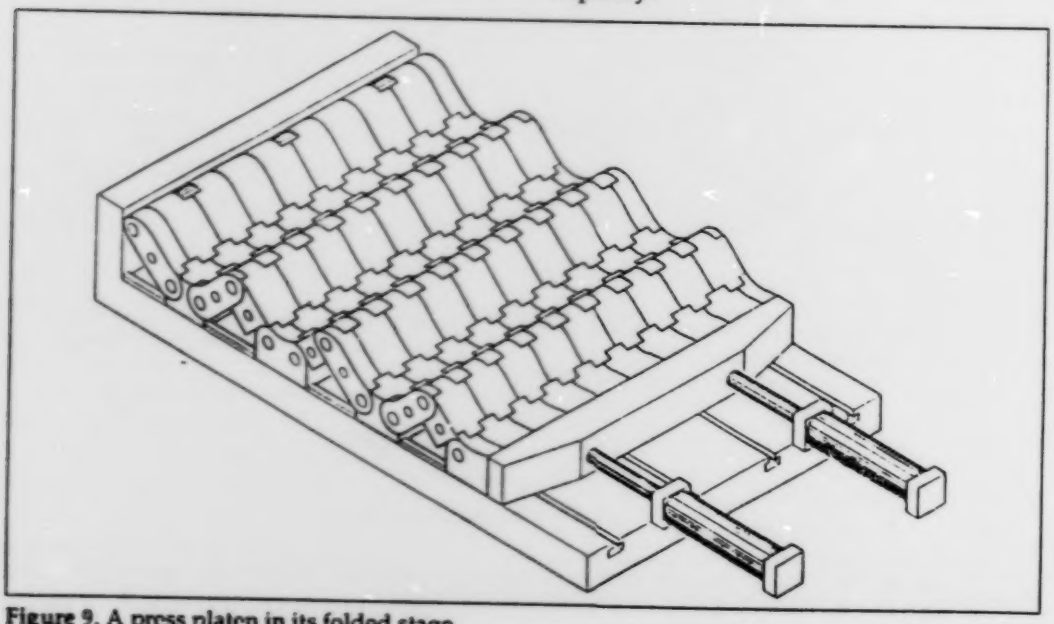

Figure 9. A press platen in its folded stage.

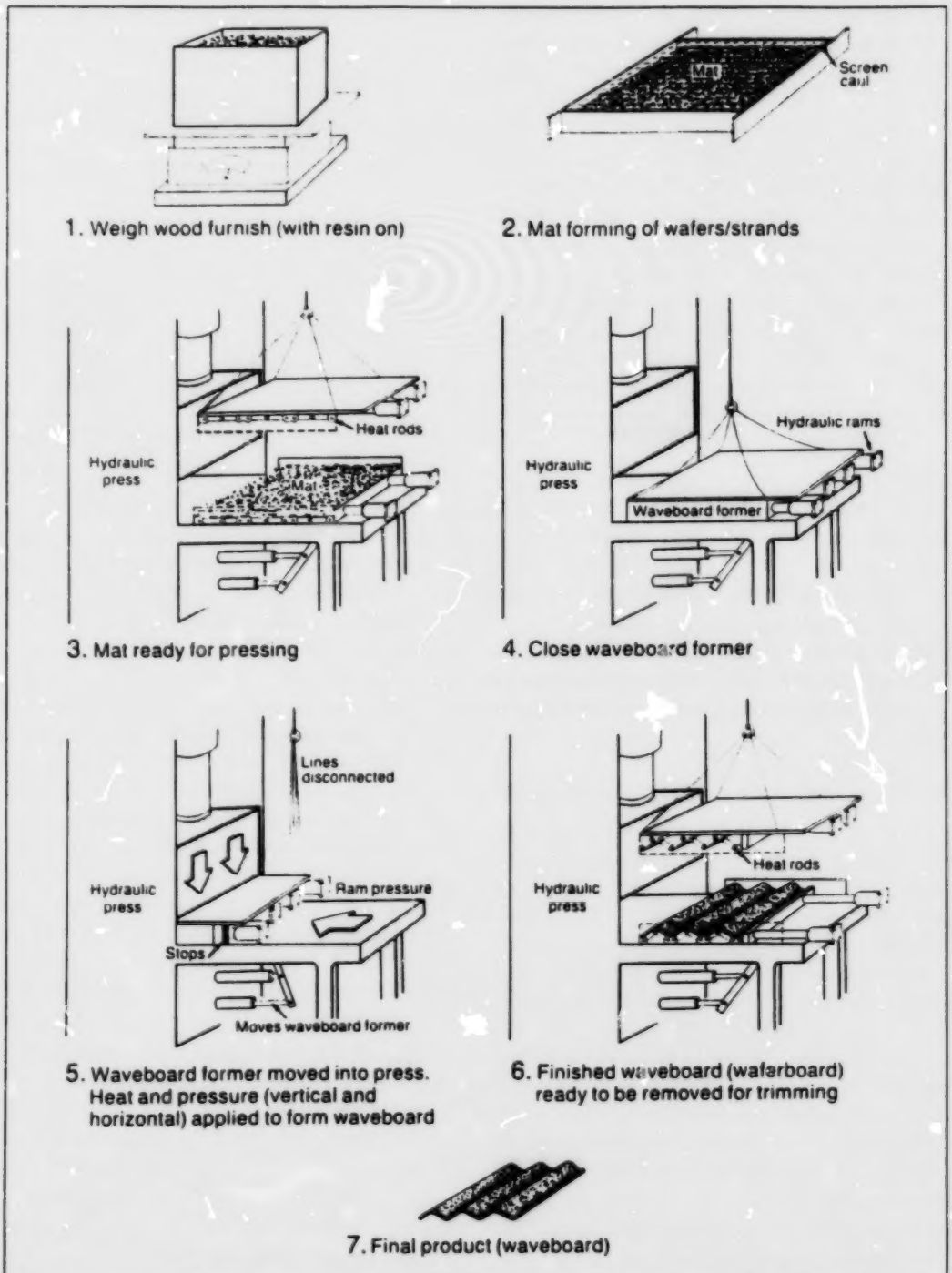

Figure 10. Principle of manufacture of corrugated waferboard (waveboard) as suggested by L. Bach and E. Stark (U.S. Pat. #4,616,991, Oct. 14, 1986).

Figure 11. A Waveboard being removed from the press.

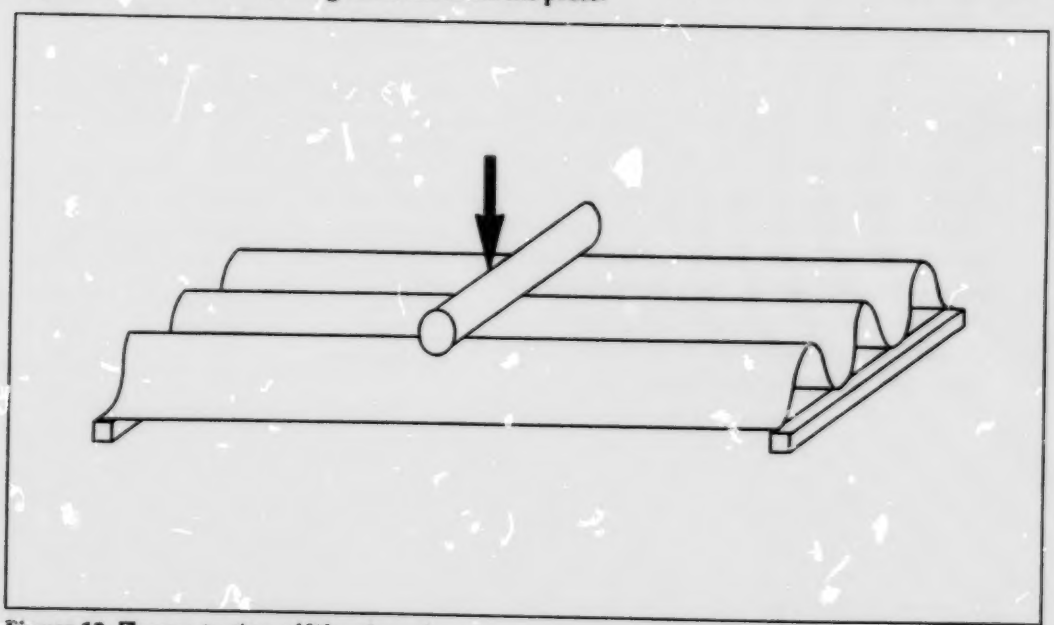

Figure 12. Flexure testing of Waveboard.

Results and Discussion

Theoretical Results

Based on the assumption that the specific material properties are unchanged, and only section properties change properties, a series of theoretical model calculations was carried out. The stiffness and strength (load capacity) of Waveboard was calculated for a number of different combinations of panel depth, skin thickness and wavelength. The relative stiffness and strength of Waveboard was calculated by comparing these properties relative to the same of flat panels of the same density, thickness and volume.

In Figures 5, 6 and 7 the relative stiffness and strength from model calculations with the WAVEFORM computer program are plotted vs. panel depth, skin thickness and wavelength. The figures show the effects very clearly. Of particular interest is the substantial effect of panel depth on stiffness and strength.

The theoretical results obtained must be taken with some reservation as other properties may influence practical uses. Also, problems arising from manufacturing could impose limitations; e.g. it is not likely panels less than 6 mm thick will be produced. However, when it comes to determining wave shapes for particular end uses where the loads are known, mathematical design models can be very useful: first, in the press platen design and later on for engineering calculations to specify waveboard for particular end uses.

Experimental Results

Several series of wavebcard panels have been flexure tested and show substantial improvement in stiffness and strength on a weight basis. Typical sample results of a test series are presented in Table 1. The stiffness of waveboard compared to flatboard was about 28 times higher and the strength was about 6 times higher.

The experimental results can also be seen to be in good agreement with the theoretical predictions shown in Figure 5.

Table 1. Bending properties of Waveboard with random oriented flakes. All boards manufactured with the same 75 mm long aspen flakes of .75 mm thickness and 3% powdered phenolic resin.

	Waveboard		Flat Waferboard	
	Value	C.V.	Value	C.V.
Panel Density (kg/m^3)	647	2.5%	661	0.9%
Unit Panel Mass (kg/m^2)	8.6	1.9%	7.3	0.7%
Wavelength (mm)	188	0.3%	–	–
Panel Depth (mm)	65	1.4%	11.1	0.9%
Skin Thickness (mm)	11.2	2.5%	11.1	0.9%
Unit Max. Moment (Nmm/mm)	4000	7.5%	626	3.4%
Unit EI (Nmm^2/mm)	20,400,000	4.6%	717,000	5.1%
MC (%)	4.1	–	2.9	–
Replications	20	–	4	–

Conclusion and Recommendations

a) A press platen system capable of manufacturing high amplitude waferboard has been designed and constructed.
b) A mathematical model for the mechanical behavior of waveboard was developed. Theoretical calculations show that the wave amplitude, wave skin thickness and wavelength of corrugated waferboard can be tailored with advantage to meet specific structural needs.
c) A laboratory manufacturing process for waveboard was developed.
d) It has been experimentally demonstrated that the stiffness and strength of wood-based building boards can be improved considerably in one direction by corrugating.
e) Scale-up product development to larger panel sizes and marketing studies are now required to assist in moving waveboard into commercial production.

Commercial Significance

The work completed by the Alberta Research Council indicates that it is technically feasible to manufacture corrugated waferboard (Waveboard™).

The results obtained indicate that the practical design spans in construction for waveboard can be extended far beyond what is possible with the flat OSB and waferboard produced today.

Acknowledgements

The Alberta Research Council acknowledges the financial contribution by Canada-Alberta Forest Resource Development Agreement for major parts of this study.

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